NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
INVENTIONS AND CONTRIBUTIONS BOARD
SPACE ACT AWARD APPLICATION

NASA FORM 1329	Inventions and Contributions Board *Space Act Award Application*	NASA Case Number: ARC-15041	Date: April 2005
SECTION I *SPACE ACT AWARD APPLICATION*			
TITLE	***The Morning Report*: Advanced Proactive Safety and System Monitoring Tool**		

1. DESCRIPTION.

a. Briefly describe the contribution. In addition, if peer-reviewed publications by contributors have been accepted on this topic in refereed journals or for refereed conference papers, please attach a copy with this form as a supplement.

***The Morning Report* is a data-intensive airline safety and information software tool** that gives aviation personnel; including safety experts, pilots, and support organizations; more insight than ever before into overall flight patterns and subtle flight characteristics. **Using sophisticated multivariate statistical algorithms, the system analyzes massive amounts of data from thousands of airline flights overnight, generating an intuitively structured report *every morning*.** The powerful algorithms that are the backbone of the analysis are combined with user-intuitive software to enable the user to drill down, and understand, the details underlying any portion of any flight. No previous technology provided ready access from the top level overview to the finest details of any part of any flight AND identified the most important portions of flights.

NASA Invention Disclosures:

1. ARC-15041-1 "Morning Report Atypicality Tool for Analysis of Aircraft Flight Data"
2. ARC-15041-2 "Information Display System for Atypical Flight Phase"

b. In what NASA program, project or mission has this contribution been used or will be utilized and to what extent? (include any non-aerospace commercialization applications)

The program has been funded and led by NASA as part of the Aviation Safety Monitoring and Modeling Project of NASA's Aviation Safety and Security Program. *The Morning Report of Atypical Flights* is one of the products of this Project whose overall objective was to provide technologies to enable the airline industry to engage in proactive management of safety risk as a strategy to maintain

or improve operational safety despite the projected growth of air traffic. This product has been recognized as making a significant contribution to the achievement of that objective by identifying unexpected events or trends that could compromise public safety. Transfer of this technology was simple because the team worked continuously in collaboration with air carriers and vendors of similar software under SAA's in an iterative process of test, evaluation, and improvement. Alpha level and Beta level testing occurred at air carriers by our technical team and the airlines safety experts, who will be the prime users of the system. It has already been licensed to one vendor who services a large number of air carriers in the US and in Europe. It is expected that *The Morning Report* will find widespread use throughout the aviation industry. It is also being considered for adaptation to the recent directions and objectives of the newly formulated Aviation Safety Program where the value of its unique capability for discovering the unexpected is expected to be recognized.

c. *Provide details describing how the contribution works or operates relative to system, subsystem, components, etc.*

The Morning Report provides aviation experts with information about flight patterns and operational conditions that they need, but normally never see. ***The Morning Report*** **allows airlines to take a proactive approach to aviation safety by identifying possible problem practices and conditions and then enabling corrective actions to be planned and implemented.** In contrast, the infamous black box recorders just document a few dozen variables for the last part of the flight and are only available for analysis in the event of an accident. With *The Morning Report*, accidents can be prevented by identifying a precursor of an unexpected potential problem. Commercial airlines are excited about this product.

Unlike other safety analysis options, *The Morning Report* provides new information about flights that aviation experts had not previously identified as noteworthy, largely because until now, neither the analytical power nor the software existed to harvest the data or allow the user to easily interpret the results. Now, the software executes **mathematical algorithms that identify flights with previously "unenvisioned" characteristics**. By analyzing key elements of an atypical flight, airlines can gain insight into potential situations in a way and to a degree never before possible. The capabilities provided by *The Morning Report* enable aviation experts to rapidly and painlessly identify rare real-world events (out of tens of thousands of flight hours), quickly display their characteristics, and **identify the situations that may be precursors to unsafe situations**.

While *The Morning Report* is a sophisticated, data-intensive computing system, **the user does not need to be a statistician or even require extensive training in use of the software!** The system automatically analyzes massive amounts of data from thousands of airline flights overnight, generating an intuitively structured report for aviation specialists to read *every morning*.

To run *The Morning Report* system, data collection instrumentation is installed on aircraft to record hundreds of data variables from each of thousands of flights throughout the day, thereby documenting the operation of the airplane. Examples of data recorded during flights include speed, roll (wing angle), equipment status (landing gear up or down), and engine temperature. Before the technology represented by *The Morning Report* was developed, these gigabytes of data went largely unanalyzed and, until now, the benefits of the knowledge that could be derived from these data were unrealized.

Periodically the data from the recording instrumentation are downloaded to a computer containing *The Morning Report's* analysis algorithms and software. The processing identifies and removes bad data and performs exceedence checks. (Exceedence checks are predefined Boolean expression comparisons of variable values and the specified criteria.) Both of these steps can be found in existing software, but from that point on *The Morning Report's* software proceeds with powerful and novel capabilities. It processes the data through a series of multivariate statistical algorithms to identify typical patterns and atypical events, and then structures the resulting intuitive report. The software can identify atypical events, even events that were never envisioned as possible by the experts. The software program generates its report each morning, providing aviation analysts with graphical displays of typical flight patterns and atypical events. The displays focus the user's attention to the key variables and the exact moment of interest during an atypical flight (see Figure 1). Additional displays are shown in the accompanying CD, which contains more details on the technical aspects of this technology. **By reviewing atypical events, the aviation expert can assess if there is a risk of an accident, and alert the community of the risk. Collectively, the community can review the findings of *The Morning Report* to determine what changes should be made to the system design or procedures to reduce the possibility of an accident.**

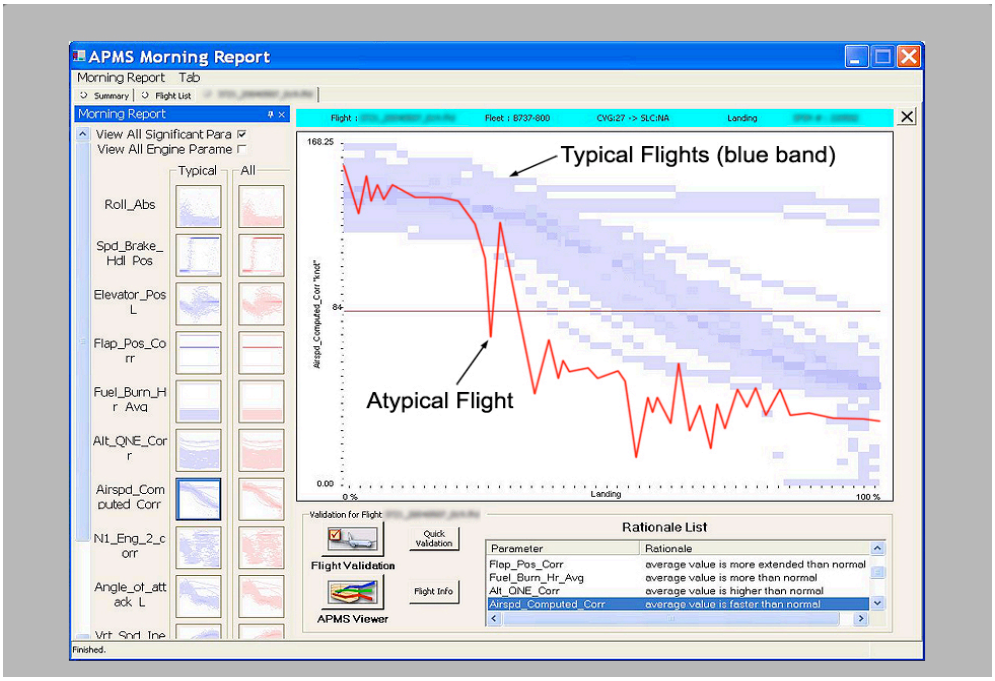

Figure 1. Atypical flights are contrasted to typical flight patterns, enabling insight to the nature and severity of the atypical observation.

For more information, see the 5-minute movie on *The Morning Report*: Advanced Proactive Safety and System Monitoring Tool in the attached CD or at http://www.pnl.gov/statistics/RandD100.htm.

2. SIGNIFICANCE.

a. Explain why the contribution is significant: scientifically, technologically, or from a humanitarian viewpoint, to the aeronautics, space community, and non-aerospace commercial activities.

The Morning Report enables air carrier safety experts to rapidly identify rare operational events (out of thousands of flights), inspect the flight characteristics, and identify ones that are of interest and warrant additional investigation.

The impact of *The Morning Report* on aviation safety has so excited safety experts in the air carrier community that the airlines, NASA, the Federal Aviation Administration (FAA), and the other stakeholders are developing the Distributed National Flight Operations Quality Assurance Archives (DNFA) to share insight gained from this software tool. The ability of *The Morning Report* to provide vital information, before it is too late, has the potential to save the lives of passengers and flight crews, not to mention millions of dollars for the airlines.

b. Estimate the degree of scientific or technological significance by a mark on the line below:

0_____1_____2_____3_____4_____**X**_____5

None ***Modest*** ***Average*** ***Major*** ***Maximum***

c. Estimate the significance of the contribution relative to a specific NASA program or mission by marking the line below:

0_____1_____2_____3_____4_____**X**_____5

None ***Modest*** ***Average*** ***Major*** ***Critical***

3. STAGE OF DEVELOPMENT.

Indicate the stage of development of the contribution by a mark on the line below:

0_____1_____2_____3_____4_____**X**_____5

Concept ***Simulated*** ***Tested*** ***Fully Developed*** ***Operational***

The system has been developed and tested, it has been licensed to a software vendor, and it is being used by several U.S. airlines today. There are enhancements envisioned to further extend its power and help improve safety in the aviation community.

4. ASSESSMENT OF USE.

a. If the contribution is now in operation, describe its performance and value within both the aerospace field and its application to non-aerospace commercial and government uses.

The Morning Report is currently in operation at two airlines (Alaska and Delta). Both airlines report very positive feedback (see the testimonial from the Alaska Airlines Vice-President of Safety and Security in the attachments). Both of these airlines (as well as TWA before its acquisition by American Airlines) have spent considerable effort in using the contribution, and provided us with feedback. Most importantly, they provided access to their proprietary data for both the development and the test and evaluation of *The Morning Report*.

SAGEM Avionics, Inc., a manufacturer and distributor of a suite of instruments dedicated to on-board acquisition of key aviation data as part of the FOQA (Flight Operational Quality Assurance) program, strongly supports the *The Morning Report* (see the testimonial from SAGEM Avionics Director of Sales and Marketing in the attachments.) Sagem has also provided us with key information on practical aspects of its implementation. SAGEM has obtained a license from NASA to produce The Morning

Report and, at its most recent Users Conference, SAGEM announced that *The Morning Report* would be incorporated in its next product release in 2006.

To date, individual airlines have benefited from the use of *The Morning Rep*ort on their own data. However, recent developments have broken the barriers on the use of proprietary data and have opened new vistas for The Morning Report. The most significant recognition of the value of monitoring the performance of the aviation system was the formulation in 2005 of the Voluntary Aviation Safety Information Sharing Program **(VASIP)** by the FAA and the aviation industry. (For additional information, see http://www.alpa.org/DesktopModules/ALPA_Documents/ALPA_DocumentsView.aspx?itemid=2416&ModuleId=3052&Tabid=256 .) . The industry and the FAA established the Voluntary Safety Information Sharing (VSIS) Aviation Rulemaking Committee (ARC) to implement the VASIP with the purpose of identifying events or trends common across air carriers that could compromise the safety of the aviation system. *The Morning Report* was viewed as sufficiently valuable for this purpose by the individual carriers who are using it to motivate the interest of the VSIS ARC and, under its auspices, the adaptation of *The Morning Report* to identify systemic issues from aggregated information will be demonstrated.

We expect that, subsequent to its demonstration in 2006, the nine major air carriers currently participating in the national archives of flight data established by the VSIS ARC will endorse the use of *The Morning Report* to provide indications of systemic issues from analysis of their aggregated data. We anticipate the growth will continue (in the United States and internationally). **It is expected to become the cornerstone of a revolutionary new approach to aviation safety.**

b. If the contribution is not now in operational use, describe its most likely or previous applications and the extent of commercial,(includes non-aerospace commercialization) government and/or NASA-specific uses.

Not applicable.

c. Will the contribution increase in value or in its applications over time and in what manner?

The value to the industry of *The Morning Report* will increase exponentially as it grows from serving the individual air carriers by enabling each to monitor its own performance into the same capability applied across air carriers to monitor the performance of the entire system.

Further, *The Morning Report* so far has been used operationally only on flight-recorded data. There is another important element of the aviation system---the air traffic management. Therefore, *The Morning Report* has been adapted for a proof-of-concept study for use on Air Traffic Control radar data to identify typical and atypical flight patterns of aircraft. This will provide an essential perspective on the performance of the aviation system to complement the information from the flight data. The value of this information is well recognized by the industry and, when they have found the way to overcome the "political" barriers to accessing those data, *The Morning Report* will be used.

Also, the thrusts of the newly reformulated Aviation Safety Program offer new opportunities for the adaptation of the capability to identify the unexpected. For example, the core technology can be extended to address a need of the Integrated Vehicle Health Management (IVHM) project for on-condition maintenance. In its current application, *The Morning Report* performs its analyses over night

of the previous day's flights to support strategic decisions for flight operations. In support of the IVHM concept, each subsystem would be monitored continuously until a reliable signature is obtained of its normal operation in each phase of flight. The statistical analysis underlying the capability of *The Morning Report* will be enhanced to identify a deviation from that normal operation in nearly real time. The finding would be linked automatically to an electronic database of the history of maintenance logs for that aircraft and to the maintenance manuals to identify the most likely causal factors and the recommended correction. This information would be available upon landing or, possibly, downloaded prior to landing.

Discussions with various NASA and commercial aerospace engineers indicate there may be other NASA programs, including space missions that could adapt this technology for their uses.

Under separate funding, Battelle/PNNL is investigating the possibility of adapting the approach to

- The electrical power grid generation and distribution system to identify typical patterns, atypical events, and precursors to significant events, thereby helping to avoid costly blackouts.
- Cyber security efforts to identify atypical message traffic that may indicate nefarious activities.

5. CREATIVITY.

What is your assessment of the creativity displayed in the conduct of this contribution, relative to the expected performance of those in similar positions?

None_____Low _____Modest_____Average_____High_____Very High_____X_____

6. RECOGNITION

What forms of recognition have been received by the contributors for this contribution? Have previous awards been made to the contributor(s) for this accomplishment? Please describe.

- In 2005, R&D magazine selected this invention as one of the top 100 inventions world-wide and further honored it by awarding it the ***Editor's Choice Award for the Product with the Greatest Impact on Safety.*** (one of only three Editor's Choice Awards).

- The **U.S. Patent Office** affirmed the novelty and significance of the core algorithms by granting a patent (#6,937,924; Statler et al., August 30, 2005, assigned to NASA).

- **NASA issued an Award for Group Achievement** for this technology signed by NASA Administrator Daniel S. Goldin.

7. TANGIBLE VALUE.

As a measure of the tangible value of this contribution, estimate the following:

a. NASA cost savings to date and in future years.*

It is the aviation industry and the flying public, rather than NASA, who will be the beneficiaries of the use of *The Morning Report*. Furthermore, *The Morning Report* was envisioned to be used as a safety-enhancing program rather than a cost-saving program. The cost savings to the industry will be realized if a strategy of proactive management of safety risk does, in fact, reduce the number of aircraft accidents despite a growth in air traffic. While prevention is a sound strategy, its effectiveness and value cannot be guaranteed, much less quantified.

**State the rationale for the above cost estimates.*

b. Current market value and potential as a commercial product or process.

The rationale for the inability to assign a definitive cost savings is given in 7.a and in 7.c. However, one might consider the value of *The Morning Report* with the perspective of its potential return on NASA's investment of its public funds. A generous estimate of the total full cost of the development and implementation of *The Morning Report* is certainly less than $15 million dollars. If the use of *The Morning Report* prevents even only one major accident, it will have paid for itself, perhaps, 50 fold.

c. Other measurable value: increased efficiency, enabling technology, improved management, etc.

The sheer popularity of this technology as judged by it successful and planned application by airlines indicates an ever-widening range of interest in its capabilities and major benefits (see the letter from Alaska Airlines). The FAA and the industry is planning for *The Morning Report* system to play a key part in the VASIP. Last, but not least, comments from numerous other airlines and their active pursuit of the rights to participate in the program with the use of this tool further attest to its positive effects.

APPLICANT'S SIGNATURE: _____ DATE: _____

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SECTION II COMMENTS AND CONCURRENCE

1. EVALUATOR

I recommend/do not recommend a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*
NASA Installation	*Contractor*	*Other*

2. EVALUATOR'S SUPERVISOR

I support/do not support a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*

3. TECHNICAL MANAGEMENT (required signature)

I support/do not support a Space Act Award for this contribution for the following reasons. Further, I verify that the contribution is significant to NASA Aeronautics and space Activities and that NASA has adopted, supported, sponsored or used this scientific or technical contribution.

Printed Name and Signature	*Title*	*Date*

4. TECHNOLOGY TRANSFER MANAGEMENT

I support/do not support a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*

TO BE COMPLETED BY AWARDS LIAISON OFFICE

5. IDENTIFICATION OF CONTRIBUTORS

Contributor Name	*Employer*	*Percentage of Contribution*
Irving C. Statler	***NASA Ames Research Center***	***5.88%***
Thomas R. Chidester	***FAA (formerly NASA)***	***5.88%***
Loren J. Rosenthal	***Battelle Memorial Institute***	***5.88%***
Thomas A. Ferryman	***Battelle / Pacific Northwest National Laboratory***	***5.88%***
Robert E. Lynch	***Battelle Memorial Institute***	***5.88%***
Gary L. Prothero	***ProWorks Corporation***	***5.88%***

Brett G. Amidan	***Battelle / Pacific Northwest National Laboratory***	***5.88%***
Robert E. Lawrence	***Battelle Memorial Institute***	***5.88%***
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Amanda M. White	***Battelle / Pacific Northwest National Laboratory***	***5.88%***
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Chris Mosbrucker	***ProWorks Corporation***	***5.88%***
Adi L. Andrei	***ProWorks Corporation***	***5.88%***
Timothy P. Romanowski	***ProWorks Corporation***	***5.88%***
Daniel E. Robin	***ProWorks Corporation***	***5.88%***
Jason W. Prothero	***ProWorks Corporation***	***5.88%***

6. PATENT INFORMATION

Patent Applied for? Y/N Granted? Y/N	*Serial Number or Patent Number* **United States Patent #6,937,924**
Application filed by: Government? *Non-Government?*	*Date Filed or Granted* **August 30, 2005**
License Granted Y/N **Y**	*Company Name:* **SAGEM Avionics, Inc.**

7. EVALUATION NUMBER 1 2 3

8. BUSINESS ADDRESS OF CONTRIBUTORS IF OTHER THAN NASA EMPLOYEES

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9. AWARD LIAISON OFFICER COMMENTS AND SIGNATURE (required)

Printed Name and Signature	*Comments*	*Date*